

CLAIMS

I Claim:

Claim 1 – A method for determining asset status, the steps including:

creating a process model comprised of a plurality of process submodels each correlative to at least one training data subset partitioned from an unpartitioned training data set and each having an operating mode associated thereto;

acquiring a set of observed signal data values from an asset;

determining an operating mode of the asset for the set of observed signal data values;

selecting a process submodel from the process model as a function of the determined operating mode of the asset;

calculating a set of estimated signal data values from the selected process submodel for the determined operating mode, and

determining asset status as a function of the calculated set of estimated signal data values.

Claim 2 – The method of claim 1 wherein the step of creating the process model comprised of the plurality of process submodels includes a step of associating at least one operating mode to each of the plurality of process submodels.

Claim 3 – The method of claim 2 wherein the selecting step includes a step of selecting the process submodel from the process model such that at least one operating mode associated with the selected process submodel substantially matches the determined operating mode.

Claim 4 – The method of claim 1 wherein the step of determining asset status includes the step of detecting the presence of a fault.

Claim 5 – The method of claim 4 wherein the detecting step includes a step of selecting a fault detection method as a function of the determined operating mode for use in detecting the presence of the fault.

Claim 6 – The method of claim 5 further including the step of making decisions on detected faults.

Claim 7 – The method of claim 6 wherein the step of making decisions on detected faults includes a step of selecting a fault decision method from a plurality of fault decision methods as a function of the determined operating mode.

Claim 8 – The method of claim 1 further including the step of performing asset control correlative to determined asset status.

Claim 9 – The method of claim 1 wherein the step of determining asset status includes the step of determining unacceptable asset status.

Claim 10 – The method of claim 9 further including the step of enabling responsive action to any determined unacceptable asset status.

Claim 11 – The method of claim 10 wherein the step of enabling responsive action includes the step of performing control to correct any determined unacceptable asset status.

Claim 12 – The method of claim 10 wherein the step of enabling responsive action includes the step of alarming off of any determined unacceptable asset status.

Claim 13 – The method of claim 9 wherein the step of determining unacceptable asset status includes the step of determining sensor signal degradation.

Claim 14 – The method of claim 9 wherein the step of determining unacceptable asset status includes the step of determining data degradation.

Claim 15 – The method of claim 9 wherein the step of determining unacceptable asset status includes the step of determining component performance degradation.

Claim 16 – The method of claim 9 wherein the step of determining unacceptable asset status includes the step of determining process operating anomalies.

Claim 17 – The method of claim 9 wherein the step of determining unacceptable asset status includes determining at least one fault condition.

Claim 18 – The method of claim 17 further including the step of ascertaining at least one fault of an asset given at least the one determined fault condition.

Claim 19 – The method of claim 18 further including the step of enabling responsive action to the asset having at least the one ascertained fault.

Claim 20 – The method of claim 19 wherein the step of enabling responsive action includes the step of performing control to correct at least the one ascertained fault.

Claim 21 – The method of claim 19 wherein the step of enabling responsive action includes the step of alarming off of at least the one ascertained fault.

Claim 22 – A system for determining asset status, said system comprising in combination:

a training data set partitionable into a plurality of training data subsets having a plurality of predefined operating modes associated therewith such that each partitioned training data subset includes at least one of said predefined operating modes associated thereto;

means for acquiring a set of observed signal data values from an asset;

means for determining an operating mode of the asset for the set of observed signal data values;

means for selecting a process submodel from a process model as a function of said determined operating mode of the asset;

means for calculating a set of estimated signal data values from said selected process submodel for said determined operating mode for performing asset surveillance, and

means for determining asset status as a function of the calculated set of estimated signal data values.

Claim 23 – The system of claim 22 further including means for determining unacceptable asset status as a function of the calculated set of estimated signal data values.

Claim 24 – The system of claim 23 further including means for performing control to correct any determined unacceptable asset status.

Claim 25 – The system of claim 23 further including means for alarming off of any determined unacceptable asset status.

Claim 26 – An asset surveillance method, the steps including:

acquiring a set of signals from an asset correlative to asset status;

digitizing the set of signals for defining a set of digitized signals;

creating a process model comprised of a plurality of process submodels each correlative to at least one training data subset partitioned from an unpartitioned training data set and each having an operating mode associated thereto;

determining an operating mode of the asset;

selecting at least one of the process submodels as a function of the determined operating mode;

producing a set of estimated signal values from the selected process submodel;

detecting a presence of a fault as a function of the set of estimated signal values from the selected process submodel for providing asset surveillance.

Claim 27 – The method of claim 26 wherein the step of producing the set of estimated signal values from the selected process submodel includes the step of selecting a parameter estimation method as a function of the determined operating mode.

Claim 28 – The method of claim 27 wherein the step of selecting the parameter estimation method includes a step of selecting the parameter estimation method from a plurality of pattern recognition methods as a function of the determined operating mode.

Claim 29 – The method of claim 27 wherein the step of selecting the parameter estimation method includes a step of selecting the parameter estimation method from a group of pattern recognition methods comprised of a System State Analyzer (SSA) method, a Bounded Angle Ratio Test (BART) method, a Vector Pattern Recognizer (VPR) method, a Vector Similarity Evaluation Technique (VSET) method, and a Probabilistic State Estimation Method (PSEM) and wherein each method is individually selected from the group of pattern methods as a function of the determined operating mode.

Claim 30 – The method of claim 26 wherein the fault detecting step includes a step of selecting a fault detection method as a function of the determined operating mode for detecting the presence of the fault.

Claim 31 – The method of claim 30 wherein the step of selecting the fault detection method includes a step of selecting the fault detection method from a plurality of pattern fault detection methods as a function of the determined operating mode.

Claim 32 – The method of claim 31 wherein the step of selecting the fault detection method from the plurality of fault detection methods includes a step of selecting the fault detection method from a group of fault detection methods comprised of a Sequential Probability Ratio Test (SPRT) method and a Bayesian Sequential Probability (BSP) method and wherein each method is individually selected, as a function of the determined operating mode, from the group of fault detection methods.

Claim 33 – The method of claim 26 further including a step of making decisions on detected faults.

Claim 34 – The method of claim 33 wherein the step of making decisions includes a step of selecting, as a function of the determined operating mode, a fault decision method from a plurality of fault decision methods.

Claim 35 – The method of claim 34 wherein the step of selecting, as a function of the determined operating mode, the fault decision method from the plurality of fault decision methods includes a step of selecting, as a function of the determined operating mode, associated threshold constants for the plurality of fault decision methods.

Claim 36 – The method of claim 26 wherein the step of selecting at least one of the process submodels includes the step of individually selecting, as a function of the determined operating mode, each of the process submodels from a plurality of models.

Claim 37 – The method of claim 36 wherein the step of individually selecting each of the plurality of process submodels includes the step of individually selecting, as a function of the determined operating mode, each of the process submodels from a group of models comprised of

a multivariate state estimation technique model, a neural network model, a mathematical model, an autoregressive moving average model, and a Kalman filter model.

Claim 38 – The method of claim 26 wherein the step of determining the operating mode of the asset includes a step of using at least one method from a group of methods comprised of a logic sequence method, a mathematical model method, a neural network method, and an expert system method for determining the operating mode of the asset.

Claim 39 – An asset surveillance system, said system comprising in combination:

a data acquisition means for acquiring a set of signals from an asset correlative to asset status;

a digitizing means for digitizing said set of signals for defining a set of digitized signals;

a process model comprised of a plurality of process submodels each correlative to at least one training data subset partitioned from an unpartitioned training data set and wherein each of said partitioned training data subsets and each of said plurality of process submodels has at least one defined operating mode associated therewith;

an operating mode determination means for determining an operating mode of said asset;

a process model selection means for selecting at least one of said process submodels as a function of said determined operating mode;

a parameter estimation means for producing a set of estimated signal values from said selected process submodel;

a fault detection means for detecting the presence of a fault as a function of said set of estimated signal values from said selected process submodel for providing asset surveillance.

Claim 40 – The system of claim 39 wherein said parameter estimation means includes means for selecting a parameter estimation method as a function of said determined operating mode for producing said set of estimated signal values from said selected process submodel.

Claim 41 – The system of claim 40 wherein said means for selecting the parameter estimation method includes means for selecting the parameter estimation method from a plurality of pattern recognition methods as a function of said determined operating mode for producing said set of estimated signal values from said selected process submodel.

Claim 42 – The system of claim 40 wherein said means for selecting the parameter estimation method includes means for selecting the parameter estimation method from a plurality of pattern recognitions methods comprised of any combination of methods from a group of pattern recognition methods comprised of a System State Analyzer (SSA) method, a Bounded Angle Ratio Test (BART) method, a Vector Pattern Recognizer (VPR) method, a Vector Similarity Evaluation Technique (VSET) method, and a Probabilistic State Estimation Method (PSEM) and wherein each method is individually selected from said group of pattern methods as a function of said determined operating mode.

Claim 43 – The system of claim 39 wherein said fault detection means includes means for selecting a fault detection method as a function of said determined operating mode.

Claim 44 – The system of claim 43 wherein said means for selecting the fault detection method includes means for selecting the fault detection method from a plurality of pattern fault detection methods.

Claim 45 – The system of claim 43 wherein said means for selecting the fault detection method includes means for selecting the fault detection method from a group of fault detection methods comprised of a Sequential Probability Ratio Test (SPRT) method and a Bayesian Sequential Probability (BSP) method and wherein each method is individually selected from said group of fault detection methods as a function of said determined operating mode.

Claim 46 – The system of claim 39 wherein said fault detection means includes means for selecting threshold constants as a function of said determined operating mode.

Claim 47 – The system of claim 46 wherein said means for selecting threshold constants includes means for selecting a threshold constant from a group comprised of a fault detection procedure false alarm probability, missed alarm probability, and system disturbance magnitude values.

Claim 48 – The system of claim 39 further including a fault decision means for making decisions on detected faults.

Claim 49 – The system of claim 48 wherein said fault decision means includes means for selecting a fault decision method from a plurality of fault decision methods as a function of said determined operating mode.

Claim 50 – The system of claim 49 wherein said fault decision means further includes means for selecting, as a function of said determined operating mode, associated threshold constants for said plurality of fault decision methods.

Claim 51 – The system of claim 39 wherein each of said plurality of process submodels are of a type individually selected, as a function of said determined operating mode, from a plurality of models.

Claim 52 – The system of claim 51 wherein each of said plurality of process submodels are of a type individually selected, as a function of said determined operating mode, from a plurality of models comprised of any combination of models from a group of models comprised of a multivariate state estimation technique model, a neural network model, a mathematical model, an autoregressive moving average model, and a Kalman filter model.

Claim 53 – The system of claim 39 wherein said operating mode determination means is selected from at least one group of methods comprised of a logic sequence method, a mathematical model method, a neural network method, and a expert system method.

Claim 54 – The system of claim 39 wherein at least one of said plurality of process submodels contains a different number of modeled signal parameters than another one of said plurality of process submodels.

Claim 55 – The system of claim 39 wherein at least one of said plurality of process submodels contains a different number of process memory matrix vectors than another one of said plurality of process submodels.

Claim 56 – The system of claim 39 wherein dimensions of at least one of said plurality of process submodels is different than dimensions of another one of said plurality of process submodels.

Claim 57 – The system of claim 39 wherein at least one of said plurality of process submodels contains different parameter estimation settings than another one of said plurality of process submodels.

Claim 58 – The system of claim 39 wherein at least one of said plurality of process submodels contains different fault detector settings than another one of said plurality of process submodels.

Claim 59 –A method for performing surveillance of an asset, the steps including:

creating a process model comprised of a plurality of process submodels each correlative to at least one training data subset partitioned from an unpartitioned training data set and each having an operating mode associated thereto;

acquiring a set of observed signal data values from the asset;

determining an operating mode of the asset for the set of observed signal data values;

selecting a process submodel from the process model as a function of the determined operating mode of the asset;

calculating a set of estimated signal data values from the selected process submodel for the determined operating mode, and

determining asset status by performing the step of comparing the set of observed signal data values to the calculated set of estimated signal data values for performing asset surveillance.

Claim 60 – The method of claim 59 wherein the step of comparing the set of observed signal data values to the calculated set of estimated signal data values includes the step of comparing the set of observed signal data values to the calculated set of estimated signal data values by using a mathematical function of at least one individual value of the set of observed signal data values and at least one corresponding individual value of the calculated set of estimated signal data values for performing asset surveillance.

Claim 61 – The method of claim 59 wherein the step of determining asset status further includes the step of using a fault detection means of a type individually selected from the group comprised of a threshold limit test, a statistical hypothesis test, a sequential probability ratio test, and a conditional probability test to evaluate the comparison between at least one individual value of the set of observed signal data values and at least one corresponding individual value of the calculated set of estimated signal data values for performing asset surveillance.

Claim 62 – The method of claim 59 wherein the step of creating the process model comprised of the plurality of process submodels includes a step of associating at least one operating mode to each of the plurality of process submodels.

Claim 63 – The method of claim 62 wherein the selecting step includes a step of selecting the process submodel from the process model such that at least one operating mode associated with the selected process submodel substantially matches the determined operating mode.

Claim 64 – The method of claim 59 wherein the step of determining asset status includes the step of detecting the presence of a fault.

Claim 65 – The method of claim 64 wherein the detecting step includes a step of selecting a fault detection method as a function of the determined operating mode.

Claim 66 – The method of claim 65 further including the step of making decisions on detected faults.

Claim 67 – The method of claim 66 wherein the step of making decisions on detected faults includes a step of selecting a fault decision method from a plurality of fault decision methods as a function of the determined operating mode.

Claim 68 – A method for performing signal source surveillance, the steps including:

creating a process model comprised of a plurality of process submodels each correlative to at least one training data subset partitioned from an unpartitioned training data set and each having an operating mode associated thereto;

acquiring a set of observed signal data values from at least one signal source;

determining an operating mode of at least the one signal source for the set of observed signal data values;

selecting a process submodel from the process model as a function of the determined operating mode of at least the one signal source;

calculating a set of estimated signal data values from the selected process submodel for the determined operating mode, and

determining status of at least the one signal source as a function of the calculated set of estimated signal data values for performing signal source surveillance.

Claim 69 – The method of claim 68 further including the step of performing control of at least the one signal source correlative to determined status.

Claim 70 – The method of claim 68 wherein the step of determining status includes the step of determining unacceptable status of at least the one signal source.

Claim 71 – The method of claim 70 further including the step of enabling responsive action to determined unacceptable status of at least the one signal source.

Claim 72 – The method of claim 71 wherein the step of enabling responsive action includes the step of performing control of at least the one signal source for which unacceptable status was determined.

Claim 73 – The method of claim 71 wherein the step of enabling responsive action includes the step of alarming off of determined unacceptable status of at least the one signal source.

Claim 74 – The method of claim 71 wherein the step of determining unacceptable status of at least the one signal source includes the step of determining at least one fault of at least the one signal source.

Claim 75 – The method of claim 74 further including the step of determining status of at least one asset associated with at least the one signal source as a function of at least the one determined fault.

Claim 76 – The method of claim 75 further including a step of performing control of at least the one asset for at least the one determined fault.

Claim 77 – The method of claim 75 wherein the step of enabling responsive action includes the step of alarming off of at least the one determined fault.

Claim 78 – The method of claim 68 wherein the step of creating the process model comprised of the plurality of process submodels includes a step of associating at least one operating mode to each of the plurality of process submodels.

Claim 79 – The method of claim 78 wherein the selecting step includes a step of selecting the process submodel from the process model such that at least one operating mode associated with the selected process submodel substantially matches the determined operating mode.

Claim 80 – The method of claim 68 wherein the step of determining asset status includes the step of detecting the presence of a fault.

Claim 81 – The method of claim 80 wherein the detecting step includes a step of selecting a fault detection method as a function of the determined operating mode.

Claim 82 – The method of claim 80 further including the step of making decisions on detected faults.

Claim 83 – The method of claim 82 wherein the step of making decisions on detected faults includes a step of selecting a fault decision method from a plurality of fault decision methods as a function of the determined operating mode.

Claim 84 – A method for performing asset control, the steps including:

creating a process model comprised of a plurality of process submodels each correlative to at least one training data subset partitioned from an unpartitioned training data set and each having an operating mode associated thereto;

acquiring a set of observed signal data values from the asset;

determining an operating mode of the asset for the set of observed signal data values;

selecting a process submodel from the process model as a function of the determined operating mode of the asset;

calculating a set of estimated signal data values from the selected process submodel for the determined operating mode, and

employing at least one of the calculated set of estimated signal data values as at least one virtual signal value for performing asset control.

Claim 85 – The method of claim 84 further including the step of using at least the one virtual signal value in place of at least one of the observed signal data values for determining asset status.

Claim 86 – The method of claim 85 further including a step of using at least the one virtual signal value in place of at least one of the observed signal data values for determining unacceptable asset status.

Claim 87 – The method of claim 86 further including a step of performing control to correct any determined unacceptable asset status.

Claim 88 – The method of claim 86 further including a step of alarming off of any determined unacceptable asset status.